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High-Energy Electron/Solid State Interaction Modeling with MONSEL

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In e-beam tools, interactions between high-energy electrons and the solid target result in backscattering, absorption, and transmission. Each of these effects may be critical to tool performance, affecting resolution, image quality, and even high voltage breakdowns. In most cases, common sense and experience suggest using low-Z materials to minimize backscattering. A more quantitative approach uses MONSEL, a software package capable of modeling e-beam interaction with complex, multi-component, multi-layered 2D and 3D structures, We report on application of MONSEL to common problems found in e-beam lithography tools.

MONSEL codes are based on up-to-date physical models of electron scattering and secondary generation, with full trajectory calculations made for boundary crossings[1]. MONSEL works with 2D multi-layer structures, where layers may be elements or chemical compounds (Fig. 1), and also with simple 3D structures shown below (Fig. 2).

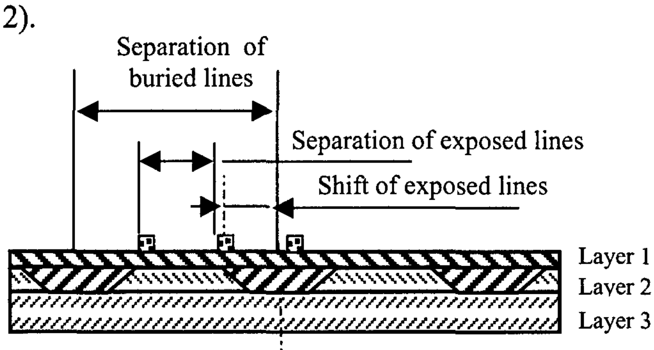

Fig. 1. Example of multi-layered 2D body for backscattering, absorption, and transmission analysis. Layers and lines are elements or chemical compounds.

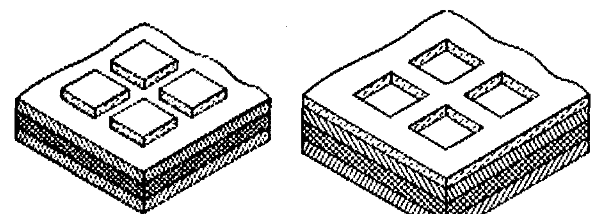

Fig. 2. Example of multi-layered 3D bodies for backscattering, absorption, and transmission analysis. Layers and lines are elements or chemical compounds.

MONSEL computes trajectories inside solids. Electrons leaving a surface are assumed to follow straight-line paths. For e-beam lithography tools, the most useful output data are backscattering (BSE) and transmitted (TRE) electron yields and energy distributions. In these tools, a 50 keV e-beam is incident upon a target consisting of several layers of photoresist and metal films on a solid substrate (see Fig. 1). Generated BSEs travel in complex electrostatic/magnetic fields, hit walls, and find their way back to the target, exposing the resist and degrading image quality. MONSEL computes BSE yields from complex surfaces, along with energy spectra (Fig. 3). In the case of 3D structures (Fig. 2), it allows analysis of BSE yields and energies for normal and oblique beam incidence. Also, it allows an e-beam to be "scanned" over complex surfaces, returning BSE/TRE yields and energies at each point (Fig. 4).

The output repeatability improves with an increased number of incident electrons launched (compare curves in Figs. 3, 4).

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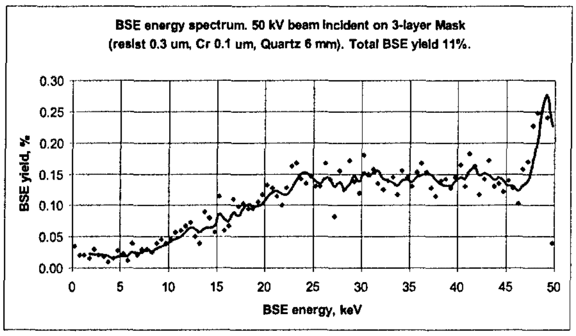

Fig. 3. BSE energy distribution from 3 layer structure (10000 incident electrons).

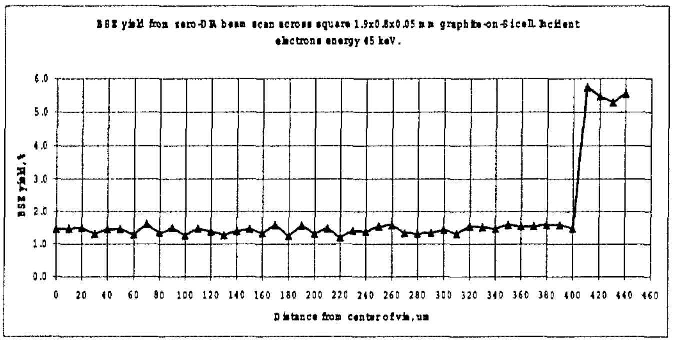

Fig. 4. BSE yield vs. beam position at 3D graphite via-on-Si-substrate (50000 incident electrons).

In modeling e-beam transmission through thin structures, MONSEL produces TRE energy and angular distributions (Fig. 5).

These capabilities can be useful in predicting how a change in configuration, coatings, etc. will affect BSE/TRE yields and their consequent undesired side effects.

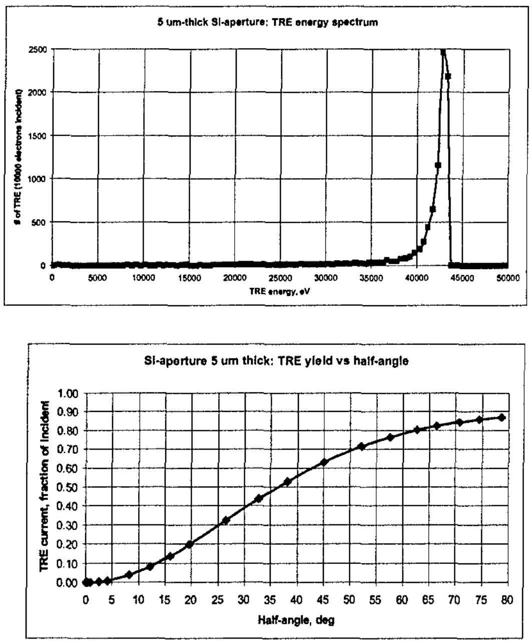

Fig. 5. 50 keV e-beam incident upon 5 μm-thick Si-wafer: energy (left) and angular (right) TRE distributions.

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References

1. J.R. Lowney, *Application of Monte Carlo Simulations to Critical Dimensions Metrology in a Scanning Electron Microscope*, Scanning Microscopy 10, 1996, pp. 667-678.